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Deep Sea Sedimentation

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An important problem in the study of microparticles in the marine environment, suspended in the water column or deposited as sediment on the ocean bottom, is the determination of provenance of the microparticles—where did they come from and by what processes were they transported to the sampling location? Two techniques of possible interest to those concerned with tracing the origins and dispersion paths of asbestos particles are described. One utilizes variations in the naturally occurring rubidium–strontium isotope system and is used to characterize a bulk sample, i.e., a large number of particles. The other utilizes scanning electron microscopy to observe variations in surface texture of individual grains which, in the case of quartz particles in the natural environment, can be related to the transport processes to which they have been subjected.

The problem in studying deep-sea sedimentation is basically that one obtains a sample of sediment and one would like to take it apart in such a way that you can tell where the different constituents came from, and from that learn something about the mechanisms — atmospheric, marine, fluvial — which were responsible for bringing the different constituents to where you find them. To this end we have used mineralogy — call it clay mineralogy — to analyze the fine grain size fraction. On suspended particulate matter filtered from sea water we are beginning to use scanning electron microscopy with energy-dispersive x-ray analysis. We use size frequency distributions as a means of characterizing the material. I will describe briefly two techniques that I have used in studying particulate matter in deep-sea sediments, suspended in sea water, and in atmospheric dusts.

The first technique is based on the natural occurrence of the radioactive isotope, rubidium-87 which has a half-life of 50 billion years. It decays to strontium-87, which is stable as are the other isotopes of strontium. Because we have to make measurements on the mass spectrometer to something like 1 part in 7,000, we measure the ratio of ^{87}Sr (which is radiogenic) to ^{86}Sr (which is nonradiogenic and stable). This ratio changes with time in rocks and in the soil minerals formed from them. And as these soil minerals are eroded and transported to the oceans, they carry with them this isotopic fingerprint of the geologic age of the continental area from which they were derived.

What we do is to analyze a deep-sea sediment sample or sample of atmospheric in exactly the same way one would a rock on which one wanted to measure its geologic age by the rubidium-strontium technique. From the elemental and isotopic data we calculate a model age on the sediment which I have called "apparent age." The true age of a sediment is the age of its deposition which, for material on the surface of the ocean bottom, is on the order of hundreds or several thousand years; but the model ages are hundreds and thousands of millions of years because of this isotopic heritage the clay minerals carry to the ocean from the continental areas from which they were derived.

Figure 1 is a map showing for this "apparent age" parameter about 150 data points in the Atlantic Ocean. The dynamic range of the

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parameter is significant—from very low ages in the South Atlantic (less than 300 million years) to very high values (more than 2000 million years) adjacent to the Canadian Shield. We are just using the parameter to help us distinguish different sources of sediment.

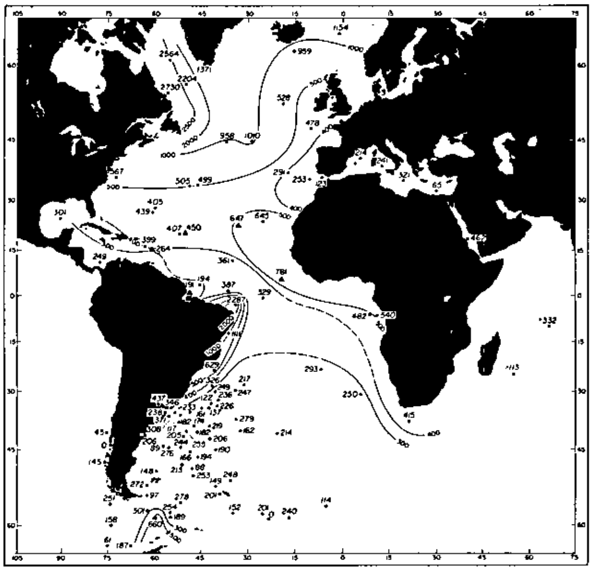

FIGURE 1. Apparent age of sediments.

For example, we have recently been using the apparent age technique in the Equatorial Atlantic to help distinguish between aeolian (wind-transported) sediment from Africa and sediment transported by streams and oceanic currents. We now have more data than shown in Figure 1, but the principles are represented. Large quantities of dust are transported by the Northeast Trade Winds from Africa all the way across the Atlantic to the Caribbean at around 10°–20°N latitude. How important is this source to the sedimentary budget of the Equatorial Atlantic? The apparent ages of dusts sampled from ships across the entire Atlantic and on Barbados are in the range of about 500 to 750 million years. Deep-sea sediments in this latitude have similar apparent ages in the eastern Equatorial Atlantic east of the Mid-Atlantic Ridge (the chain of submarine mountains that bisects the Atlantic into two major basins). Apparent ages of sediments west of the Mid-Atlantic Ridge, however, are significantly lower than either the dusts or the sediments east of the Ridge. We thus are able to conclude that wind-borne African dusts appear to be the major influence on deep-sea sediments east of the Ridge and despite their occurrence across the entire Atlantic, aeolian dusts deposited in the deep-sea west of the Ridge are diluted by sediments from other sources, e.g., rivers like the Amazon and deep oceanic bottom currents which transport sediments in suspension from high to low latitudes.

Given sufficient sample material this technique could be used to characterize sources of asbestos from terrains of different geologic ages.

The second technique concerns much smaller samples — individual quartz grains — and attempts to discern provenance or origins from textural characteristics on the surface of the grain. My application of the technique to deep-sea sediments was in conjunction with David Krinsley of Queens College (C.U.N.Y.) who discovered the technique and has done most with it. It is based on the fact that different environments imprint different characteristic textural patterns on the surface of a quartz grain. Quartz transported by glacial processes has a characteristic texture which is different from that of quartz transported by a stream or on a beach, which is still different from quartz from a desert. Thus environments to which sediment has been subjected leave their characteristic mark on quartz surface texture. Our application was to attempt to discern different origins of the sediment in the Argentine Basin east of southern South America. The rationale is that sediment from Argentina would have a fluvial (river transported) or desert texture, while sediment transported by oceanic currents from Antarctica would have a glacial texture. We found, in fact, that a large portion of the sediment did not come from the immediately adjacent continent — South America — but from Antarctica.